

MULTILAYER WIRING BOARD AND SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a semiconductor device such as a multifinger type device <sup>for example,</sup> used in high-frequency power amplifiers for portable communication terminal.

Power enabling communication from a position distant from a communication relay point is required of portable communication terminals such as portable telephones, <sup>In order to achieve successful operation of such portable</sup> ~~and thus~~ high-frequency power amplifiers <sup>in communication</sup> ~~in~~ <sup>developed to have</sup> ~~used~~ <sup>terminals,</sup> portable communication terminals have been increased in capacity.

As a measure for increasing <sup>the capacity of such</sup> high-frequency power amplifiers ~~in capacity,~~ it is possible to provide an increase in current for high output by modularizing and arranging many bipolar transistors (hereafter, <sup>simply</sup> referred to as transistors) in parallel at predetermined spacing.

However, if transistors are arranged in parallel at predetermined spacing, centrally positioned transistors are thermally affected by adjacent transistors to become highest in thermal resistance (hereinafter referred to as calorific value).

In this manner, when transistors having high calorific values are present among <sup>the</sup> transistors arranged in parallel, <sup>the</sup> current flows through transistors of high

✓ calorific values in a concentrated manner, and, hence,  
✓ the transistors possibly <sup>suffer</sup> cause thermorunaway ~~to be~~  
✓ ~~broken~~ which can lead to a breakdown of the transistors.

✓ Therefore, it is conventional that transis-  
✓ <sup>in such arrangements</sup> tors are varied in size according to calorific values  
✓ thereof. *An example of such a*

~~In addition, this kind of~~ conventional  
technique is disclosed in, for example, Japanese Patent  
Unexamined Publication Nos. 2-219298 and 5-152340.

10 In recent years, it has been increasingly  
demanded to make portable communication terminals small  
in size, lightweight, and low in cost, as well as to  
✓ increase <sup>their</sup> power amplifiers in power, as mentioned above.

As matters stand, it is naturally inevitable ~~to that the~~  
✓ 15 ~~miniaturize~~ power amplifiers. <sup>mentioned</sup> ~~miniaturized~~  
✓ <sup>as such,</sup> Thereupon, when transistors themselves are

made small in order to miniaturize a power amplifier,

✓ it is found that <sup>a</sup> heating temperature <sup>is undesirably high for</sup> of transistors

✓ disposed on ends of a row of transistors arranged in

✓ 20 parallel ~~is high~~. The reason for this is believed to

be that, while heat generated in centrally positioned

transistors is transferred and diffused to adjacent

✓ transistors, heat transfer is small in endwise  
✓ positioned <sup>positioned at the ends of the group of transistors. This</sup> transistors, ~~to cause~~ an increase in

✓ 25 <sup>for such end transistors</sup> calorific value, since there are transistors only on one  
✓ <sup>of the end transistors</sup> side, to which heat <sup>can</sup> ~~should~~ be diffused.

✓ In the case where as a measure <sup>is provided</sup> for cooling  
such heat, thermal vias <sup>can be</sup> are formed in a wiring board, as

disclosed in Japanese Patent Unexamined Publication  
No. 2-219298, <sup>With such an arrangement, it is</sup> possible <sup>that</sup> in heat distribution inside a  
semiconductor substrate makes it impossible to ignore a  
part <sup>portion</sup> of heat <sup>the</sup> which flows in a direction (hereinafter,  
5 referred to as "planar direction") orthogonal to a  
thickness-wise direction of the semiconductor  
substrate, in addition to one-dimensional flow of heat  
in <sup>the</sup> thermal vias, in the event of insufficient diffusion  
of heat in the semiconductor substrate. That is, when  
10 heating areas in the semiconductor substrate are  
distant from positions of the thermal vias in the  
planar direction in a wiring board, thermal resistance  
correspondingly increases.

Also, when radiation paths in a wiring board  
15 which mounts a semiconductor substrate <sup>are</sup> ~~is~~ not suitable,  
<sup>as is</sup> in the case where via holes and PHS are used, as  
disclosed in Japanese Patent Unexamined Publication No.  
5-152340, it is difficult to reduce thermal resistance.  
In particular, there is a need of making PHS, which an  
20 expensive material such as gold plating is used to  
form, as thin as possible in thickness from a viewpoint  
of cost reduction. However, when PHS is made thin,  
diffusion of heat in a PHS layer becomes extremely  
insufficient in a planar direction, and, while thermal  
25 diffusion remains insufficient, heat is conducted to a  
multilayer wiring board via a brazing material. There-  
fore, when via holes and thermal vias are positionally  
distant from each other, thermal resistance of the

entire wiring board cannot be reduced from a semiconductor device with the result that the via holes and thermal vias cannot serve as radiation paths.

Further, in the case where a semiconductor substrate having a small thermal conductivity <sup>is used, for example,</sup> like a GaAs substrate ~~is used~~, and in the case where an insulating film adapted to function as a thermally insulating material is present between a device circuit surface and a substrate mother material <sup>such as</sup> like a SOI (silicon on insulator) substrate, there is the possibility that radiation electrodes provided on that surface of the semiconductor substrate, on which a circuit is formed, serve inadequately <sup>This is</sup> due to the fact that thermal resistance of paths, along which heat is discharged to the semiconductor substrate and the wiring board from heating areas such as emitter base junctions through wiring and radiation electrodes, becomes larger than that of <sup>other</sup> paths, along which heat is discharged directly to a back surface of the semiconductor substrate from the heating areas, because thermal resistance is increased when heat passes through the semiconductor substrate. In the well-known technique disclosed in Japanese Patent Unexamined Publication No. 8-227896, radiation electrodes are simply formed on a semiconductor substrate with a diffusion layer for contact therebetween, and ~~so~~ such technique <sup>cannot</sup> be said to be sufficiently effective from a viewpoint of heat radiation in a thickness-wise

direction of a semiconductor substrate, a wiring board, or a semiconductor substrate.

✓ In this manner, <sup>previous</sup> ~~any~~ conventional technique cannot provide ideal heat radiation.

5 An object of the present invention is to provide a multilayer wiring board, in which thermal resistance of radiation paths is reduced to provide an improvement in radiation effect.

#### SUMMARY OF THE INVENTION

10 The above object is attained by a multilayer wiring board having through-holes in a thickness-wise direction, wherein a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction thereof, and entire areas,  
15 which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate are included in areas ☐ which the through holes in the multilayer wiring board  
20 occupy.

✓ Also, the above object is attained by <sup>a</sup> ~~A~~ multilayer wiring board having through holes in a thickness-wise direction, wherein a semiconductor substrate mounted on the multilayer wiring board has  
✓ 25 through-holes in a thickness-wise direction thereof, and entire areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal

to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate partly overlap areas which the through holes in the multilayer wiring board occupy.

- ✓ 5 Also, the above object is attained by <sup>a</sup>~~A~~ multilayer wiring board having a through hole or holes in a thickness-wise direction, wherein respective heating areas inside a semiconductor substrate mounted on the multilayer wiring board are included in areas, 10 which the single or plural through holes in the multilayer wiring board occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate.

- ✓ Also, the above object is attained by <sup>a</sup>~~A~~ 15 multilayer wiring board having through holes in a thickness-wise direction, wherein a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction thereof, <sup>for this arrangement,</sup> ~~and~~ heat flow one-dimensionally through the through 20 holes in the semiconductor substrate and the through holes in the multilayer wiring board in the thickness-wise direction when heat flows out to a surface of the multilayer wiring board opposite to that surface thereof, on which the semiconductor substrate is 25 mounted, via the through holes in the semiconductor substrate and the through holes in the multilayer wiring board.

Also, the above object is attained by an

✓ arrangement (1) in which conductive layers are formed on side surfaces of the through holes, or interiors of the through holes <sup>are formed of</sup> comprise a conductive material.

✓ Also, the above object is attained by an  
5 arrangement (2) in which a semiconductor element is mounted, in which conductive layers are formed on side surfaces of the through holes, <sup>in which</sup> or interiors of the through holes <sup>are formed of</sup> comprise a conductive material.

✓ Also, the above object is attained by an  
10 arrangement (3) in which wirings, which connect heating areas in the semiconductor substrate mounted on the multilayer wiring board, are electrically connected to the through holes in the semiconductor substrate, ~~and~~  
✓ <sup>With this arrangement,</sup> electrical connection is effected through the heating  
15 areas, the wirings, the through holes of the semiconductor substrate, the through holes of the multilayer wiring board, and a surface of the multilayer wiring board, on which the semiconductor substrate is not mounted, in this order.

20 Also, the above object is attained by a multilayer wiring board having through holes in a thickness-wise direction, wherein the distribution density of calorific values in a plane orthogonal to the thickness-wise direction of a semiconductor  
25 substrate mounted on the multilayer wiring board substantially coincides with the distribution density in a plane orthogonal to the thickness-wise direction of the through holes.

Also, the above object is attained by a multilayer wiring board having through holes in a thickness-wise direction, wherein the distribution density of calorific values in a plane orthogonal to the thickness-wise direction of a semiconductor substrate mounted on the multilayer wiring board substantially coincides with the distribution density of large and small cross-sectional areas in a plane orthogonal to the thickness-wise direction of the through holes.

Also, the above object is attained by a wiring board, wherein a semiconductor substrate having through holes, which are connected to emitter wirings connected to emitters of heterojunction bipolar transistors and extend through the semiconductor substrate in a thickness-wise direction and which have conductive layers on sides thereof or inside thereof, is mounted on the multilayer wiring board, and the through holes in the semiconductor substrate and the through holes extending through the wiring board in a thickness-wise direction are connected to each other, and wherein conductive layers are provided on sides of or inside of the through holes in the semiconductor substrate and the wiring board, and areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate are included in areas, which the through



holes in the multilayer wiring board occupy.

Also, the above object is attained by a multilayer wiring board, wherein emitter fingers of heterojunction bipolar transistors are arranged on a semiconductor substrate, the semiconductor substrate is mounted on a wiring board, which has through holes in a thickness-wise direction, and the through holes in the wiring board have on sides or inside thereof a material of good thermal conductivity, *In this arrangement,* and ~~wherein~~ *those* areas, which emitter fingers, except *those* emitter fingers at both ends of the emitter fingers, electrically connected by the same emitter wirings occupy in a plane orthogonal to the thickness-wise direction of the semiconductor substrate and the wiring board, are included in areas *which the* through holes in the wiring board occupy, *On the other hand,* but ~~areas,~~ which the fingers at the both ends occupy, are not included therein.

Also, the above object is attained by a semiconductor device including a plurality of finger-like emitter electrodes or source electrodes, and at least one via hole arranged in rows in a first direction on a semiconductor substrate, in which semiconductor device the emitter electrodes or the source electrodes are connected to a conductive layer formed on a back surface opposite to that surface, on which the electrodes are formed, through the via hole, *On this arrangement,* ~~and in~~ *the* ~~which~~ semiconductor device rows comprising the emitter electrodes or source electrodes, and the via hole are

arranged in parallel in a second direction orthogonal to the first direction, and the via holes are positionally offset from one another among adjacent rows, or adjacent rows are positionally offset from one another.

Also, the above object is attained by an arrangement in which the multilayer wiring board has through holes formed on sides thereof or inside thereof with a conductive layer, and areas, which the via hole of the semiconductor device occupies, overlap areas, which the through holes of the multilayer wiring board occupy in a plane orthogonal to the thickness-wise direction.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view of a multilayer wiring board according to the present invention.

Figs. 2A to 2C are views showing a fundamental embodiment according to the present invention.

Fig. 3 is a cross sectional view showing a prior art semiconductor substrate and a multilayer wiring board in the prior art

Fig. 4 is a view showing the positional relationship between via holes and thermal vias in a prior semiconductor substrate.

Fig. 5 is a cross sectional view showing an embodiment in which thermal vias are arranged below heating areas.

Fig. 6 is a cross sectional view showing heat flows in a semiconductor substrate.

✓  
5 Fig. 7 is a cross sectional view showing an embodiment (1) in which thermal vias are arranged below via holes and heating areas.

✓  
Fig. 8 is a cross sectional view showing an embodiment (2) in which thermal vias are arranged below only central portions of heating areas.

✓  
10 Fig. 9 is a cross sectional view showing an embodiment (3) in which a circuit surface is formed on a SOI substrate.

Fig. 10 is a cross sectional view showing a typical cross-sectional structure of a prior heterojunction bipolar transistor.

15 Fig. 11 is a view showing an arrangement of electrodes and via holes in a prior semiconductor substrate.

✓  
20 Fig. 12 is a view showing an embodiment (4) in which via holes are positionally offset between adjacent rows.

✓  
Fig. 13 is a view showing an embodiment (5) in which rows of emitters are positionally offset between adjacent rows.

✓  
25 Fig. 14 is a view showing an embodiment (6) in which rows of emitters are positionally offset between adjacent rows and via <sup>holes,</sup> ~~holes,~~ and thermal vias positionally overlap one another. *in which*

DESCRIPTION OF THE EMBODIMENTS

✓ [Incidentally,] <sup>A</sup> a semiconductor device used in high frequency power amplifiers for pocket communication terminals etc. is constituted conventionally, as shown in Fig. 3, by stacking a multilayer wiring board 3, a brazing material 2, and a semiconductor device 1 in this order from below. In a semiconductor device of such structure, though not shown, a plurality of parts, such as a chip capacitor and a resistor, as well as the above-described semiconductor device 1, are mounted on the wiring substrate 3.

✓ Also, a mother material of the above-described multilayer wiring board 3 is a ceramic-based, a glass-ceramic-based, or a glass-epoxy-based electric insulating material. Generally, [there has been] <sup>a problem is often</sup> caused [a problem] that, since electric insulating materials also have a low thermal conductivity, [they in] <sup>of such materials</sup> use, while in an original state result in an increase in thermal resistance of an entire device, and ~~even~~ if a back side of the device is kept at temperature below a certain value, a heating area in the semiconductor device <sup>can experience</sup> ~~can~~ extremely rises in temperature to cause thermorunaway of or breakage, in some cases, of the device.

✓ In order to solve the <sup>a</sup> problem, ~~that~~ technique is adopted [in] which a plurality of pillar-shaped members (hereinafter, referred to as "thermal via") 4 with conductivity and high thermal conductivity are arranged to substantially extend through the multilayer

wiring board 3 in a thickness-wise direction, a semiconductor device 1 is mounted thereon by means of a conductive brazing material 2 such as solder, the thermal vias are connected to a common grounding electrode on a mother board from a back side of the multilayer wiring board 3 and thermal connection is also ensured therebetween to reduce thermal resistance between heating areas in the semiconductor device 1 and the back side of the wiring board 3.

10                   Meanwhile, in order to enhance output and efficiency of the power amplifier, there has been developed a device of the type [ ] in which ~~where~~ hetero-bipolar transistors (HBTs) are formed on a compound semiconductor substrate such as GaAs or the like. Fig. 15 10 shows an exemplary cross sectional structure of the device and Fig. 11 shows an exemplary plan in the case where a plurality of comb-type finger electrodes are aligned. Such compound semiconductor substrate ~~in-~~ *p. suffer from* ~~volves~~ a problem that ~~it has~~ *they have* a low thermal conductivity as compared with Si-based substrates, and ~~is~~ *are effectively* ~~insulating~~ *are used to* ~~except portions [ ] which form semiconductors~~ *devices*. Therefore, in the case where a compound semiconductor substrate such as GaAs is used to form a semiconductor device, a technique is adopted [ ] in which thermal resistance 25 between heating areas on a surface of the device and a back side of a wiring board is reduced by providing through holes (hereinafter, referred to as "via hole") 5 in a portion of the device, providing plated layers

such as gold plating on a back surface of the device and on side surfaces of the through holes to thereby electrically connect the front and back surfaces of the device via the via holes 5, and using the plated layers 5 as thermal diffusion plates. Generally, the plated layers used as the thermal diffusion plates are called a plated heat sink (PHS) 6.

Meanwhile, a major part of heat generated in circuits formed on the surface of the semiconductor device 1 spreads in a planar-wise manner and passes through the device in a thickness-wise direction, and diffuses in the PHS 6 in a planar-wise manner to be transmitted to the multilayer wiring board. However, a part of such heat <sup>spreads</sup> ~~gets~~ to locations distant from the heating areas via a wiring layer on the surface of the device to enable reducing thermal resistance to some extent.

In particular, a problem of heat radiation in a planar-wise manner exhibits itself markedly as the semiconductor substrate becomes thin. Conventionally, the above problem has not come to the fore since semiconductor substrates <sup>generally</sup> are fairly thick <sup>enough</sup> to be ~~much~~ effective in planar-wise diffusion of heat within a substrate, and distribution of heat flux is substantially uniform on a back surface of the semiconductor substrate. However, when <sup>as</sup> heating areas in a semiconductor substrate are increased in packaging density and <sup>the plan</sup> size <sup>decreases</sup> ~~in plan becomes small~~, thermal

resistance in <sup>a</sup> thickness-wise direction causes a <sup>significant</sup> so much problem, which makes it necessary to make the semiconductor substrate thin and to reduce the thermal resistance.

5                    However, when a semiconductor substrate is made thin, planar-wise diffusion of heat inside of the semiconductor substrate becomes insufficient, and so distribution of heat flux on a back surface of the semiconductor substrate is affected by the calorific  
10 value and distribution of heating areas on the front surface of the substrate to lead to an increase <sup>d</sup> thermal resistance in a planar-wise direction unless heat thermal conductive members such as thermal vias are arranged in appropriate positions. Thus, a problem is  
15 caused that thermal resistance is not reduced <sup>even</sup> though the substrate is made thin.

Meanwhile, in designing <sup>an</sup> arrangement of electrodes and via holes 5 in a plane where circuits of a semiconductor device are formed, it has been  
20 conventionally general to align rows of electrodes in position in the case where, as shown in Fig. 11, a plurality of rows of electrodes are connected in parallel to function as one semiconductor element.  
With such <sup>an</sup> arrangement, irrespective of whether via  
25 holes 5 are arranged in a center or ends of the rows of electrodes, the via holes 5 are arranged substantially in a line in a longitudinal direction in the figure. Moreover, when the number of the electrodes in the

✓ respective rows of electrodes involves no scatter, positions of the electrodes will be also arranged substantially in a line in a longitudinal direction in the figure. However, such <sup>an</sup> arrangement presents the  
5 following issues.

Here, it is assumed that heating areas are mainly constituted by emitter base junctions disposed below emitter electrodes 7. In the case of an arrangement in a cross sectional view shown in Fig. 10,

✓ 10 a heating area is in the vicinity of ~~near~~ a junction of a highly doped p type GaAs base layer 18 and a highly

doped n type InGaP emitter layer 20. <sup>below the emitter wiring 10B which is connected to an emitter wiring 10A</sup> As described <sup>(noting that the emitter wiring 10B is constructed of a different material than emitter 10A).</sup> above, heat generated in this area is discharged in a thickness-wise direction of a semiconductor substrate 1  
15 while diffusing in longitudinal and transverse directions in Fig. 11. However, when fingers are laid down as shown in Fig. 11, via holes and ends of rows of electrodes are aligned in position, which causes a problem that fingers arranged in positions distant from  
20 the via holes and from the ends of rows of electrodes are restricted in radiation paths to become <sup>likely</sup> liable to <sup>have a</sup> rise in temperature. <sup>significant</sup>

Hereafter, an embodiment of the present invention will be described with reference to Figs. 1  
25 and 2.

Fig. 1 is a cross sectional view showing the positional relationship between a multilayer wiring board according to the present invention and a



semiconductor substrate mounted thereon. In addition, Fig. 1 shows a typical case where a material of the semiconductor substrate 1 is GaAs and circuits are heterojunction bipolar transistors (hereinafter, referred to as "HBT"). However, it goes without saying that a material of the semiconductor substrate 1 is not limited to GaAs, and the circuits are not limited to the HBTs.

Figs. 2A to 2C are views showing, in cross section containing an entire semiconductor substrate, the positional relationship between a multilayer wiring board and a semiconductor substrate. Thus, Fig. 2A is a cross sectional view in a X direction, Fig. 2B is a cross sectional view in a Y direction, and Fig. 2C is a plan<sup>view</sup>. In addition, while there is no specific limitation on determination of the X and Y directions, it is assumed here that the semiconductor substrate is rectangular in a planar direction and that the X direction is parallel to one side of the rectangle and the Y direction is orthogonal to the X direction.

In Fig. 1, a plurality of emitter electrodes 7 are arranged in rows shown in Fig. 2C, collector electrodes 8 are arranged between the adjacent emitter electrodes 7 in a row, and base electrodes 9 are formed in a manner to sandwich individual emitter electrodes 7 therebetween. It is defined relative to the thickness-wise direction of the semiconductor substrate 1 that a side contacting the PHS 6 is lower, and a side, on

✓ which a circuit surface is formed, is <sup>the</sup>upper<sup>side</sup>. At this time, the emitter electrodes 7 and the emitter wirings 10 are shown in the structure shown in Figs. 1 and 2. However, constituent members such as collector wiring, 5, base wiring, other circuit parts, wire pads and so on are omitted for the purpose of simplification.

Emitter electrodes 7 are connected to emitter wirings 10 in Fig. 1 and Fig. 2. In addition, the emitter wirings 10 are connected to the via holes 5 10 provided in the semiconductor substrate. Side surfaces ✓ of the via holes 5 are covered with a material [ ] which is the same as that of the PHS 6 and has good thermal and electrical conductivity, or interiors of the via ✓ holes 5 are filled with a material [ ] which has good 15 thermal and electrical conductivity. In the case where the semiconductor substrate 1 is formed of an electrically conductive material, it is desired that the above-described processing is performed after an insulating film is formed on the surfaces of the via 20 holes 5. Also, the semiconductor substrate 1 is mounted on the multilayer wiring board 3 through a brazing material 2 such as solder and an electrically conductive adhesive. In addition, while the wiring ✓ board 3 is multilayered here, the present inventions is 25 applicable even to a single-layer wiring board, which has wiring patterns on upper and lower sides thereof.

Thermal vias 4 are arranged on the multilayer wiring board 3. Similarly to the via holes 5, side

✓ surfaces of the thermal vias 4 are formed with a layer  
✓ of a material (1) which is thermally and electrically  
✓ conductive, or interiors of the thermal vias 4 are  
filled with a material (2) which is thermally and  
5 electrically conductive. In the present invention, an  
entire area occupied by the via holes 5 is included in  
an area occupied by the thermal vias 4 in the XY plane  
in the figure. Therefore, when heat loss generated in  
emitter base junctions in the vicinity of the emitter  
10 electrodes 7 is discharged to a back surface of the  
multilayer wiring board 3 via the emitter wirings 10  
and via holes 5, discharge of heat is effected one-  
dimensionally in a thickness-wise direction through the  
via holes 5, brazing material 2, and thermal vias 4 in  
15 this order in the semiconductor substrate 1. Accord-  
ingly, there is no need <sup>for</sup> of heat transmission in a  
planar direction in, for example, the PHS layer 6 and  
the brazing material 2. <sup>Thus,</sup> ~~and so~~ it is possible to  
efficiently discharge heat loss, generated in the  
20 emitter base junctions in the vicinity of the emitter  
electrodes 7, to an underside of the multilayer wiring  
board 3, and to discharge heat outside of the  
substrate.

As mentioned above, Figs. 3 and 4 are views  
25 showing an exemplary arrangement of a conventional  
semiconductor substrate 1 and a multilayer wiring board  
3, in which the positional relationship between the  
thermal vias 4 and via holes 5 is not prescribed.

✓ Therefore, there is caused a problem that, as shown in  
the new plan in Fig. 4, the via holes 5 and thermal vias 4 <sup>become</sup> get  
out of position relative to each other, <sup>accordingly, even</sup> and, though the  
multilayer wiring board 3 has thermal resistance as an  
5 element equivalent to that of the embodiment of the  
present invention shown in Figs. 1 and 2, thermal  
resistance of the entire structure is increased in  
terms of radiation paths in the planar direction.

✓ However, in the case where the number of the  
10 via holes 5 is plural, as shown in Fig. 2, the number of  
the thermal vias 4 may also be plural. Even if the  
number of the thermal vias 4 is one as a whole, or one  
for each via hole 5, or one for a plurality of via  
holes 5, the same effect can be achieved in any one of  
✓ 15 the above cases, so long as that condition is met in  
which an entire area occupied by the via holes 5 is  
included in an area occupied by the thermal vias 4 in  
the XY plane in the figure. Also, while Fig. 2 shows  
✓ an arrangement in which the thermal vias 4 are  
✓ 20 regularly arranged outside the area occupied by the  
thermal vias 4, the thermal vias 4 are free in cross  
section, shape, number, and arrangement, provided that  
✓ the above-mentioned condition is met. So, without  
other circuit components having large heat loss, it  
25 does not matter if any thermal vias 4 are not arranged  
elsewhere. On the contrary, when there are other  
circuit components with large calorific values, thermal  
vias 4 may be separately provided below the circuit

components.

A further embodiment of the present invention will be described with reference to Fig. 5. Fig. 5 is a cross sectional view showing the positional  
5 relationship between a multilayer wiring board and a semiconductor substrate mounted thereon in this embodiment. In addition, the same numerals as those in Figs. 1 and 2 designate the same parts or elements as those in the <sup>earlier</sup> figures, and so an explanation therefor  
10 will be omitted.

In this embodiment, an area, in which emitter electrodes 7 is arranged, is included in an area occupied by via holes 4 in a XY plane.

Fig. 6 is a schematic diagram showing  
15 radiation paths in a cross section in the embodiment of the present invention shown in Figs. 1 and 2. Heat generated in respective emitter base junctions is mainly divided into a part that goes from the emitter wirings 10 to the underside of the multilayer wiring  
20 board 3 via the via holes 5 and thermal vias 4, and a part that directly goes to the underside of the semiconductor substrate 3 not through the emitter wirings 10 while diffusing in the XY directions, and  
25 flows in the XY directions in the <sup>interior</sup> ~~inferior~~ of the multilayer wiring board 3 or in the PHS 6 and the brazing material 2. While heat is finally discharged outside due to heat conduction or heat transmission, thermal resistance of the thermal vias 4 and thermal

✓ resistance of only the multilayer wiring board 3a form  
✓ a thermally parallel circuit so that a major part of ~~the~~ <sup>mother</sup> heat passes through the thermal vias 4 and a part of ~~the~~ heat passes through the multilayer wiring board 3 in  
5 the thickness-wise direction. The smaller the thermal  
✓ conductivity of the ~~mother~~ <sup>primary</sup> material of the multilayer  
✓ wiring board 3 is, the larger an amount of heat passing through the thermal vias 4 becomes.

In the embodiment of the present invention  
10 shown in Fig. 5, an area, in which the emitter electrodes 7 are arranged, is included in an area occupied by the thermal vias 4 in the XY plane, so that heat going to an underside of the device not through the emitter wirings 10 does not flow in the XY  
15 directions, but flows into the thermal vias 4 in a one-dimensional manner. Therefore, it is possible to reduce the total thermal resistance.

A still further embodiment of the present invention is shown in Fig. 7. This embodiment has a  
20 feature in that areas, in which via holes 5 and emitter electrodes 7 are arranged, respectively, are included in an area occupied by thermal vias 4 in a ~~XY~~ <sup>XY</sup> plane. Therefore, heat loss generated in emitter base junctions in the vicinity of the emitter electrodes 7  
25 comprises a part passing through the emitter wiring 10 and via hole 5 and a part that directly goes to the underside of the semiconductor substrate 1 while diffusing in the XY directions, the both parts flowing

into the thermal vias 4 in a one-dimensional manner,  
✓ thereby enabling reducing <sup>loss of</sup> the total thermal resistance  
from the heating areas to the underside of the multi-  
layer wiring board 3.

5 A further embodiment of the present invention  
is shown in Fig. 8. The embodiment shown in Fig. 8 is  
substantially the same as that shown in Fig. 5 but is  
constructed such that thermal vias 4 are not arranged

[only] below emitter electrodes disposed nearest to  
10 ends (chip ends in the figure) of the semiconductor  
substrate 1. When a plurality of emitter electrodes 7

are arranged in rows on the semiconductor substrate 3,  
*with each row having the emitter electrodes connected to the same emitter,*  
temperature of emitter base junctions in the vicinity *increasing, the*  
1 of the respective emitter electrodes 7 is such that a

15 plurality of emitters are high in temperature for those  
close to centers of the emitters thus arranged and  
low in temperature for those in peripheral portions

thereof. With a high frequency element such as a power  
✓ amplifier for portable phones, ~~(there is the need of)~~ *it is necessary*  
20 making <sup>2</sup> temperature distribution as uniform as possible

✓ because, in particular, when HBTs are mounted, *scatter differences*  
✓ in temperature of respective emitters arranged in  
✓ parallel causes <sup>differences</sup> scatter <sup>creating</sup> in current flowing through the  
✓ respective emitters, ~~to have~~ the possibility that

25 positive feedback is applied to cause oscillation of  
elements and eventual breakage thereof.

✓ To meet such <sup>9</sup> need, an arrangement is  
preferable, in which thermal vias 4 are arranged

✓ immediately below those ~~ones~~ *emitter* disposed centrally of emitters thus arranged, but not arranged immediately below the emitters in the peripheral portions. As a result, it is possible to preserve thermal resistance

5 of the emitters in the peripheral portions as it is, and to decrease only thermal resistance of ~~ones~~ *emitters which are* disposed centrally of ~~the~~ *the* emitters thus arranged, so that it is possible to reduce ~~scatter~~ *the difference* in temperature as well as to reduce the entire thermal resistance.

10 In addition, the cross sectional views shown in Figs. 1, 5, 7, and 8 depict arrangements *[u]* in which a single thermal via 4 is allotted to a single via hole 5 and a single thermal via 4 is allotted to six emitter electrodes 7, respectively. However, the thermal vias  
15 4 are free in number, size, and way of arrangement so long as the conditions prescribed in the respective embodiments are met, *Thus, if* ~~and so~~ a single thermal via 4 may be allotted to a plurality of via holes 5 or *a* one-to-one correspondence may be applied. Also, a single *thermal* ~~thermal~~  
20 via 4 may be allotted to a plurality of emitter electrodes 7 or *a* one-to-one correspondence may be applied. Further, Fig. 5 shows an arrangement *[u]* in which the emitter electrodes 7 are divided into two groups, though there is no showing of any via hole 5.  
25 However, it does not matter if the emitter electrodes are divided into a plurality of groups, or arranged individually according to a certain rule.

Also, cross sectional views or plan views



showing the respective embodiments of the present invention shown in Figs. 1, 2, 4, and 7 show arrangements in which only one via hole 5 per row is provided centrally of a row of the emitter electrodes 7 connected to one another by a line of emitter wiring 10. However, the number and arrangement of the via holes 5 are optional for a row of a plurality of emitter electrodes 7 connected to one another by a line of emitter wiring 10, and so it does not matter if one via hole 5 is arranged at both ends of the row and a plurality of via holes are arranged in the row.

Fig. 9 shows a constitution of a further embodiment of the present invention. In this embodiment, emitter fingers 7 are mounted on a SOI (silicon on insulator) substrate 11. With the SOI substrate, individual transistors 12 are enclosed by an insulating film 13 so as to reduce a parasitic capacitance, with the result that the insulating film 13 causes areas occupied by the respective emitter electrodes 7 to be thermally insulated from one another. With such an arrangement, other portions than layers such as emitter wirings 10 cannot serve as a radiation path, so that heat loss generated passes the semiconductor substrate 1 via the emitter wirings 10 and the via holes 5. With such an arrangement, areas occupied by the via holes 5 are made to be included in areas occupied by thermal vias 4 in the XY plane, so that it is still more likely possible to promote heat

conduction in the thickness-wise direction and to reduce thermal resistance from the heating areas to the underside of the multilayer wiring board 3.

A still further embodiment of the present invention is shown in Fig. 12. Fig. 12 shows the positional relationship among emitter electrodes, emitter wirings, and via holes in this embodiment. In this embodiment, via holes 5 are arranged in positions offset from one another in adjacent rows of emitters.

10 In the case of the arrangement in a conventional semiconductor device shown in Fig. 11, positions of the third and fourth emitter electrodes 7 from the left in the figure and the third and fourth emitter electrodes 7 from the right in the figure are distant from the via

✓ 15 holes 5 and also from ends of rows of emitters, ~~thus~~ *This* causing <sup>as</sup> a problem that adequate radiation paths cannot be ensured and, ~~so~~ <sup>consequently,</sup> temperature is liable to rise.

However, the arrangement shown in Fig. 12 makes it possible to reduce a distance from an emitter electrode

✓ 20 7 to the via holes 5 <sup>which are not</sup> arranged in ~~not~~ a row, to which the emitter electrode 7 concerned is connected, but ~~instead to~~ adjacent rows, whereby emitter electrodes 7 having been liable to rise in temperature with a conventional semiconductor device decrease in temperature, <sup>This makes</sup> making it

✓ 25 possible to maintain <sup>a constant</sup> temperature distribution ~~constant~~ and to reduce thermal resistance of the entire semiconductor device.

A still another embodiment of the present

invention is shown in Fig. 13. Fig. 13 shows the positional relationship among emitter electrodes, emitter wirings, and via holes in this embodiment. Rows of emitters themselves are positionally offset from adjacent rows in this embodiment, and so the via holes 5 are also arranged offset from those in adjacent rows. As a result, heat generated in emitter fingers 7 disposed near ends of rows can be improved in performance of radiation since portions free of heating areas are present in the periphery. Also, heat generated in the emitter fingers 7 distant from ends of rows and also from the via holes 5 in the rows can be improved in performance of radiation of heat discharged to the via holes 5 in the adjacent rows.

15 In addition, while positions of the via holes 5 and rows of fingers are periodically offset from one another in the embodiment of the present invention shown in Figs. 12 and 13, the present invention has no <sup>requirement</sup> reason for such periodicity in the way of such  
20 offsetting, and so it goes without saying that the same effect can be obtained in <sup>an</sup> that arrangement in which heating areas in the respective emitter fingers are constant in temperature distribution and temperature is decreased as compared with the case where no counter-  
25 measure is adopted, though such arrangement deviates somewhat in periodicity.

A further embodiment of the present invention is shown in Fig. 14. Fig. 14 shows the arrangement of

heating areas in the semiconductor substrate 1 and of thermal vias in the multilayer wiring board 3. Thus, this embodiment is obtained by a combination of the embodiment of the present invention shown in Fig. 1 and  
5 the embodiment of the present invention shown in Figs. 12 and 13. Such arrangement of heating areas, via holes and thermal vias makes it possible to achieve further reduction of thermal resistance.

✓  
✓ 10 In this manner, it is possible, according to the present invention, to reduce thermal resistance of an entire device, since heat generated in respective heating areas can be effectively conducted to an underside of a multilayer wiring board. Also, since heat generated in respective heating areas can be  
✓ 15 effectively ~~let out~~ <sup>released</sup> to via holes and a semiconductor substrate, thermal resistance of an entire device can be reduced.

✓  
✓ 20 It is possible according to the present invention to provide a multilayer wiring board <sup>having an</sup> improved in radiation effect, since radiation paths leading from emitter wirings to an underside of a multilayer wiring board through via holes and thermal vias can be reduced in thermal resistance.

CLAIMS

1. A multilayer wiring board having through holes in a thickness-wise direction,

wherein a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction thereof, and entire areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate are included in areas, which the through holes in the multilayer wiring board occupy.

2. A multilayer wiring board having through holes in a thickness-wise direction,

wherein a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction thereof, and entire areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate partly overlap areas which the through holes in the multilayer wiring board occupy.

3. A multilayer wiring board having a through hole or holes in a thickness-wise direction,

wherein respective heating areas inside a semiconductor substrate mounted on the multilayer wiring board are included in areas, which the single or plural through holes in the multilayer wiring board

occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate.

4. A multilayer wiring board having through holes in a thickness-wise direction,

wherein a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction thereof, and heat flow one-dimensionally through the through holes in the semiconductor substrate and the through holes in the multilayer wiring board in the thickness-wise direction when heat flows out to a surface of the multilayer wiring board opposite to that surface thereof, on which the semiconductor substrate is mounted, via the through holes in the semiconductor substrate and the through holes in the multilayer wiring board.

5. The multilayer wiring board according to one of claims 1 to 3, wherein conductive layers are formed on side surfaces of the through holes, or interiors of the through holes comprise a conductive material.

6. The multilayer wiring board according to one of claims 1 to 3, wherein a semiconductor element is mounted, in which conductive layers are formed on side surfaces of the through holes, or interiors of the through holes comprise a conductive material.

7. The multilayer wiring board according to claim 1, wherein wirings, which connect heating areas in the semiconductor substrate mounted on the

multilayer wiring board, are electrically connected to the through holes in the semiconductor substrate, and electrical connection is effected through the heating areas, the wirings, the through holes of the semiconductor substrate, the through holes of the multilayer wiring board, and a surface of the multilayer wiring board, on which the semiconductor substrate is not mounted, in this order.

8. A multilayer wiring board having through holes in a thickness-wise direction,

wherein the distribution density of calorific values in a plane orthogonal to the thickness-wise direction of a semiconductor substrate mounted on the multilayer wiring board substantially coincides with the distribution density in a plane orthogonal to the thickness-wise direction of the through holes.

9. A multilayer wiring board having through holes in a thickness-wise direction,

wherein the distribution density of calorific values in a plane orthogonal to the thickness-wise direction of a semiconductor substrate mounted on the multilayer wiring board substantially coincides with the distribution density of large and small cross-sectional areas in a plane orthogonal to the thickness-wise direction of the through holes.

10. A wiring board,

wherein a semiconductor substrate having through holes, which are connected to emitter wirings

connected to emitters of heterojunction bipolar transistors and extend through the semiconductor substrate in a thickness-wise direction and which have conductive layers on sides thereof or inside thereof, is mounted on the multilayer wiring board, and the through holes in the semiconductor substrate and the through holes extending through the wiring board in a thickness-wise direction are connected to each other, and wherein conductive layers are provided on sides of or inside of the through holes in the semiconductor substrate and the wiring board, and areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate are included in areas, which the through holes in the multilayer wiring board occupy.

11. A multilayer wiring board,

wherein emitter fingers of heterojunction bipolar transistors are arranged on a semiconductor substrate, the semiconductor substrate is mounted on a wiring board, which has through holes in a thickness-wise direction, and the through holes in the wiring board have on sides or inside thereof a material of good thermal conductivity, and wherein areas, which emitter fingers except emitter fingers at both ends of the emitter fingers electrically connected by the same emitter wirings occupy in a plane orthogonal to the thickness-wise direction of the semiconductor substrate



and the wiring board, are included in areas, which the through holes in the wiring board occupy, but areas, which the fingers at the both ends occupy, are not included therein.

12. A semiconductor device including a plurality of finger-like emitter electrodes or source electrodes, and at least one via hole arranged in rows in a first direction on a semiconductor substrate, in which semiconductor device the emitter electrodes or the source electrodes are connected to a conductive layer formed on a back surface opposite to that surface, on which the electrodes are formed, through the via hole, and in which semiconductor device rows comprising the emitter electrodes or source electrodes, and the via hole are arranged in parallel in a second direction orthogonal to the first direction, and the via holes are positionally offset from one another among adjacent rows, or adjacent rows are positionally offset from one another.

13. The semiconductor device according to claim 12, wherein the multilayer wiring board has through holes formed on sides thereof or inside thereof with a conductive layer, and areas, which the via hole of the semiconductor device occupies, overlap areas, which the through holes of the multilayer wiring board occupy in a plane orthogonal to the thickness-wise direction.

ABSTRACT OF THE DISCLOSURE

A multilayer wiring board having through holes in a thickness-wise direction, in which wiring board a semiconductor substrate mounted on the multilayer wiring board has through holes in a thickness-wise direction, and entire areas, which the through holes in the semiconductor substrate occupy, in a plane orthogonal to the thickness-wise direction of the multilayer wiring board and of the semiconductor substrate are included in areas, which the through holes in the multilayer wiring board occupy.